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Abandoned Oak coppice on both sides of the Jura Mountains: dendroecological growth models highlighting woodland development and management in the past

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Introduction

As documented in numerous written sources, coppice, for oak particularly, was a common practice in historical times in Western Middle Europe (Corvol-Dessert 2002, Buridant 2004). The same assumptions can be derived from dendrotypology for earlier periods (Billamboz, 2010). Considering the high potential of dendroarchaeology to highlight relationships between human societies and woodland development, or consequences of socio-economic changes on the forest structure (Billamboz 2003, Bernard et al. 2007, Girardclos & Petit accepted), reference possibilities to related dendroecological studies are rather scarce and sometime divergent (Haneca et al. 2005, Copini et al. 2007, 2009). Therefore, tree-ring investigations of abandoned oak coppice have been recently undertaken on both sides of the Jura Mountains in order to assess the variability of radial growth as well as to gain a first insight into the stand structure and dynamics. First results are presented here from four plots representing different conditions of forest management based on coppicing. Within the scope of dendrotypology, analysis focuses on the following aspects: (1) comparison of age trend pattern and growth rate in the first years of regeneration between trees generated from stool and from acorns. (2) Influence of degree of competition and social status of the shoots: coefficient of slenderness, sapwood proportions. (3) Abrupt growth changes resulting from coppice rotations and further woodland practices.

Site location and woodland management

Plots 1, 2 and 4 are located in Eastern France, in the forests of Chantrans, a small village on the first French Jura plateau (47°03'N-6°11'E, 620 m asl., Fig.1). The soil type, inherited from Jurassic limestone, is brunisol where a brownish B horizon is identified, without any evidence of clay accumulation. The typical depth is 30 to 50 cm. Humus indicator of intense biological activity is an eutrophic mull. The tree species composition shows a mixture of oaks (*Quercus robur and Qu. petraea),* beech (*Fagus sylvatica*), hornbeam (*Carpinus betulus*) and ash (*Fraxinus excelsior*). Hornbeam is located at its highest level for the region. Woodland at that place takes two very different structures under forest management. Communal forests are large woods managed as coppices-with-standards during the 19th century and through the first quarter or even the first half of the 20th century. Under this type of management, the density of the dominant trees, the standards, remains low. The crowns are rarely in contact. The coppice is exploited in the understory, with stump shoots harvested at each rotation, and the future dominant trees chosen mainly from seed trees (Lanier *et al.*, 1994). Most of these forests are now designed to high-forest conversion with a very scarce participation of vegetative sprouting. The second case is more specific of the Chantrans region, forest still a large area but, under private property, shows a mosaic structure typical of sylvo-pastoral practices. In this integrated approach, the same owner or a more complicated group of owners and users can benefit of farming (grazing) and forest products. Forest management mostly based on coppicing interests a small unit and is more related to economic

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activity or to the community needs than a planification. In consequence of socio-economic changes occurred around 1960, these actual Oak (*Quercus robur / petraea*) stands managed as coppice to provide firewood and bark for tanning are now developing past their usual rotation length.

Near Neuchâtel (Fig.1), plot 3 is part of a municipal forest on the lower Swiss slope of Jura (47°01'N-6°57'E, 690 m asl.). At the latitude of Besançon and Neuchâtel, climate of western and eastern slope of Jura is differenced by annual total of precipitation: 1100 mm at Besançon and 930 mm at Neuchâtel. Winter temperature are colder at Neuchâtel, the mean value of mean temperature for the period December to February is 1,3°C and 2,8°C at Besançon. Spring temperature for the period from March to May are going in them way: 8,8°C and 10°C, but summer are more similar: 17,5°C and 18,4°C for June to August. Finally the assumption can be made the vegetation season is shorter at Neuchâtel and the summer is more dry. The soil type, also inherited from Jurassic limestone, is a brunisol, but the situation of the plot in a slope increasing the drying sensitivity. The stand is dominated by Oaks (*Quercus petraea*) regularly harvested by coppicing for the needs of fuel in the past and is now designed to high forest conversion by a public administration.

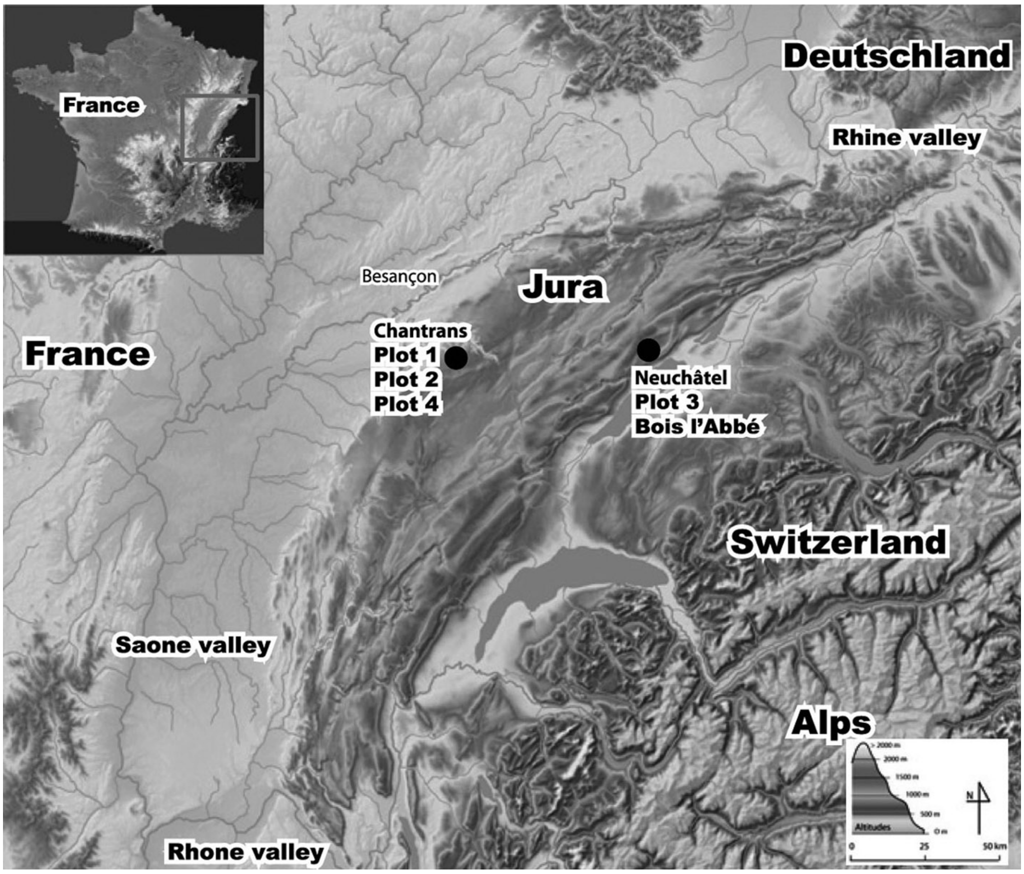

Figure 1: Map of the Jura mountains with location of the four investigated plots.

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Material and methods

Table 1: Descriptive statistics. H moy: average total height with standard deviation between brackets, DBH moy: diameter at breast height, Age: age average in three generation classes deducted from measured and estimated rings of shoots, rm: mean correlation between shoot series.EPS:express population signal.

Site	Owner	H moy (m)	DBH moy (cm)	No of radii	No of shoot	Age 1st	Age 2nd	Age 3rd	rm	EPS
Chantrans plot 1	private	18 (1,5)	17 (3,5)	36	18	53	-	-	0,61	0,977
Chantrans plot 2	private	21 (2,1)	32 (4,2)	16	8	67	86	108	0,58	0,898
Bois l'abbé plot 3	public	-	34 (3,9)	16	8	162	193	-	0,48	0,981
Chantrans plot 4	private	19 (0,4)	22 (2,7)	14	7	63	81	-	0,52	0,978

According to the aspects of research mentioned above and related to the abandonment of coppicing the sampling method was not selective and retained first a large number of suppressed shoots. At Chantrans, diameter at breast height and total height are registered for each shoot sampled. Becker (1992) indicate the height/diameter ratio (H/D) or slenderness of oak tree depends on its average past competition status, firstly related to silvicultural treatment, and is independent of the site conditions. Nevertheless H/D ratio is also related to age. Young trees grow more preferentially in height than old ones. It is actually not possible to propose a model of the relation between slenderness and age in the case of oak coppice because of lacking sample depth. In consequence, for the presentation of these first results, the H/D ratio is interpreted taking into account age classes based on the coppice generations.
Samples take two forms, cores and cross sections if trees were cut by the owner. Coring has been made at 1 meter high, lower on the stem as usual in order to optimize the expression of the cambial age of relatively young and small trees (Tab. 1). To determine the age of shoot when core borer failed the pith, innermost missing rings are estimated using xylem rays convergence and the average width of the 5 first measured rings. This value is compared as appropriate to cross sections from the same plot, to age of sprout and diameter at breast height. Tree-ring widths were measured at least along two radii with a Lintab and TSAP device (Rinn 1989). The chronology development was performed using the Sylphe programme (Meignier, copyright GNU-GPL 2001). To assess the chronology construction for each plot, mean correlation and Express Population Signal (EPS) of "shoots series" have been computed, taking account of intra and between tree variability (Tab.1). Values are systematically above the level defined by Wigley et al. (1984), thus indicate that trees are dependant of common factors and chronologies are statistically relevant. Particular attention was paid to the evaluation of the sapwood proportions as indicator of social status and stand density. Finally cambial age trend is estimated by averaging raw ring width series age estimated aligned and growth trend in the plot chronology is exhibited by application of a Loess function (Cleveland, 1981) on raw data.

Results

Trees in plot 1 (Fig. 2) have been clear-cutted for tanning around 1958. Accordingly, the regenerated coppice stand is even-aged and all shoots have around 53 rings (Tab. 1). Consecutively to the abandonment of harvesting the stand has not be thinned since this date. Competition between shoots of the same or different stools has now a strong impact on growth reflected (1) in slenderness of the stem (Fig. 4) and (2) in strong negative age trend and narrow rings (Fig. 3). This is the fact of reduced conditions of light for suppressed trees (Roussel 1978). The H/D ratio is globally higher than in the other plot. Within the plot conditions and for the given age class, order the series based on H/D ratio returns to judge the influence on shoot of competition. Dominated shoots show a slower duraminisation, a larger number of thin sapwood rings than dominant ones. In this situation, the Pearson coefficient of correlation between H/D ratio and sapwood number of rings reach the value of 0,45.

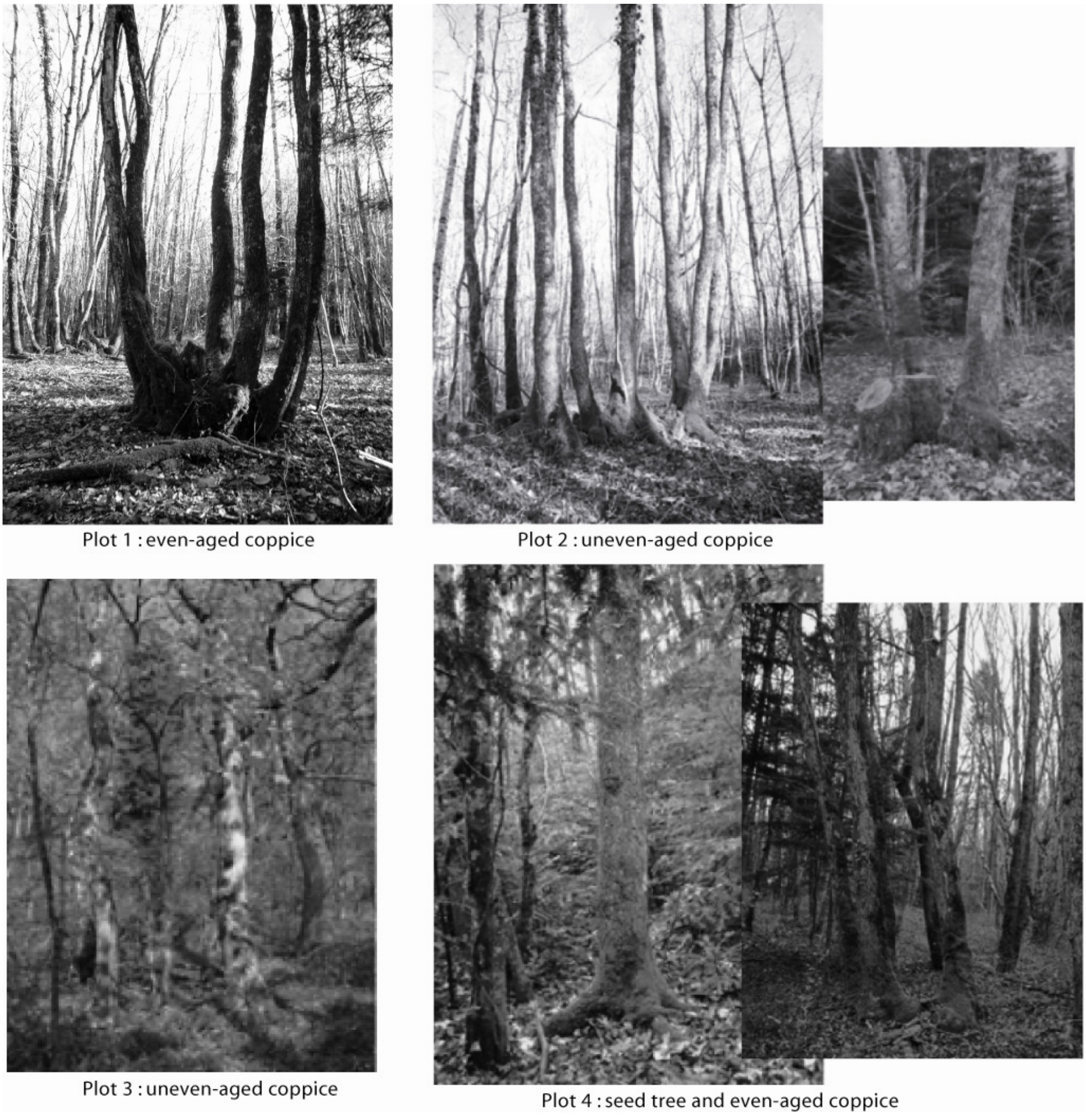

Figure 2: Pictures from the different plots.

In plot 2 (Fig. 2), stand management cannot really be distinguished between harvesting or regeneration cuts and thinning cuts. Logging conducted after owner's needs mainly based on fire wood supply. Accordingly, stand structure is still uneven-aged. Tree age spans three generations of shoots (Tab. 1). The oldest trees sampled regenerated near 1900. The second and third generations indicate cutting operations 22 to 25 years and ca. 50 years later. During the last 70 years harvesting has been more or less abandoned. Concerning the form of the coppice trees, two cases are observed: 1) all the shoots from a stool have the same age, which indicates the entire tree has been harvested at one time; 2) a selective cut concerned only one part of the shoots. In consequences, the trees and shoots remaining in place benefited differently of the thinning measure. In comparison with other plots H/D ratio is lower but sampling doesn't permit a comparison at constant age (Fig. 4). Growth trends take different forms between generations (Fig. 3). The oldest trees started to grow with their largest rings. For the second generation first new rings are wide but growth reaches the highest rate 15 to 20 years later. Certain series show very narrows rings in first years indicating the shoot cannot break free of an intense constraint during a certain time. In this sylvo-pastoral context browsing is an assumption.

Plot 3 (Fig. 2), is an especially old coppice where some trees are 200 years old. Growth rate is globally lower than in other plots in relation to local and climate settings. Two main tree generations have been sampled. Their respective growth begin shows a lag of 30 years, here probably a rotation length between two cuts. Selective cuts are highlighted by repeated growth release of shoots. More generally, the growth rate of the oldest trees increased at the beginning of the second generation linking hereby the growth release to the thinning operations (Fig. 3).

The stand plot 4 consists of last relicts of an even-aged coppice in competition with oak seed trees and spontaneous silver fir (*Abies alba*) regeneration from plantations (Fig. 2). H/D ratio positioned in the high part of the points distribution whatever the age (Fig. 4), indicates seed trees are in relatively dense stand.

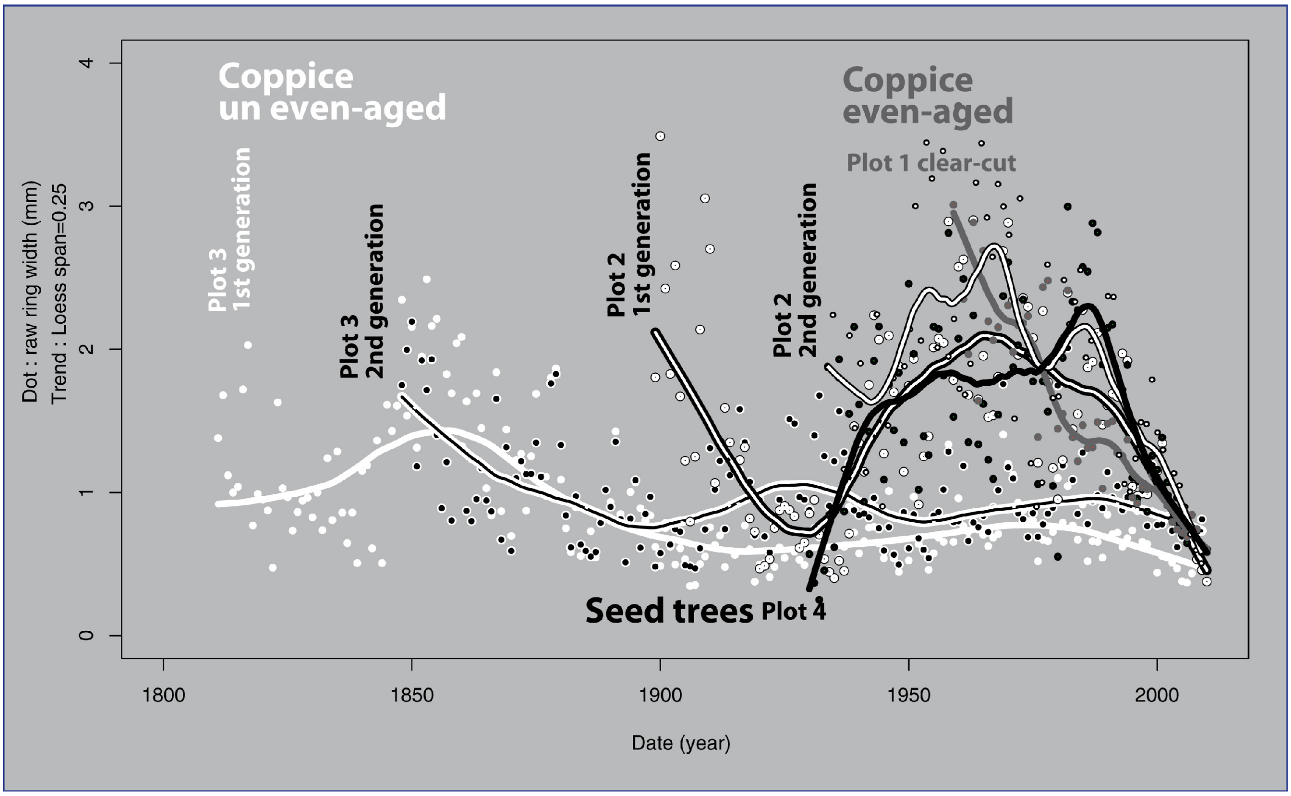

Figure 3: Selection of average chronologies computed for each plot generation of shoot. Dot showing raw average and solid line growth trend as define by a Loess function.

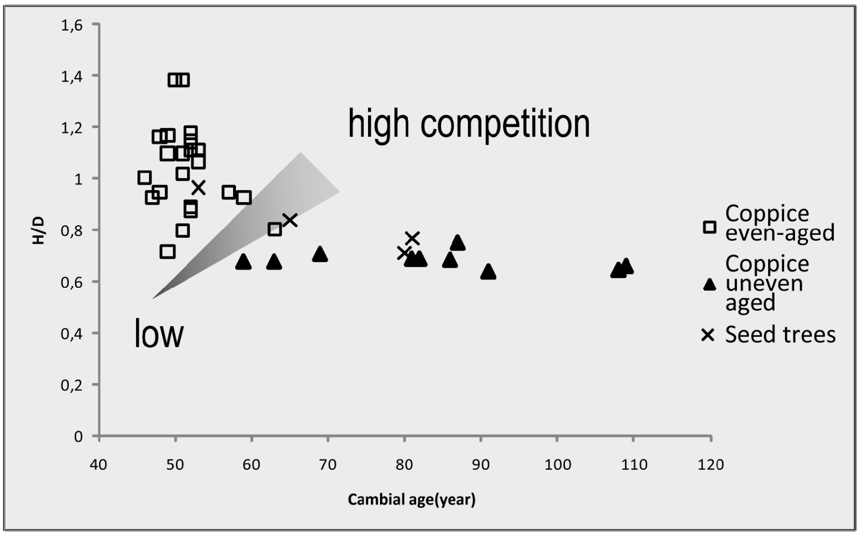

Figure 4: Relation between H/D ratio, slenderness, and cambial age.

Discussion

Field observations, information from the owners and age estimation permit to describe two types of coppice on the sites: 1), consecutively to a (local) clear-cut the coppice structure is even-aged, 2) consecutively to selective harvesting the coppice structure is uneven-aged.

Trend patterns

Trend patterns exhibited from raw mean chronologies are presented for each plot after classification of “shoot series” according age and competition status, in a similar way followed by the dendrotypology method used in dendroarchaeology (Fig. 3). This representation allows considering common information for a generation of shoots according to chronology and age trend. One can observe that most of the chronologies from coppiced stands are beginning with 5 to 15 wide rings. This is the more obvious for even-age coppice whatever the competition the shoots undergo. For uneven-aged coppice, the largest rings of the series are not systematically the youngest ones. Competition conditions are more complexes especially if the cut deals with the dominant shoots, sparing the weakest ones, or if browsing occurs. Sometimes, growth release is observed consecutively to selective cut, in individual series and for a generation in the stand. Comparatively, trees regenerated from acorn in the same site reach a maximum of growth rate after 15 to 20 years.

Age trends comparison

“Age-aligned” series collectively describe the functional form of the overall cambial age related growth trend typical for the species, on a given site or in a given region (Esper et al. 2003). Although, if aged-aligned series from large datasets are classified according silvicultural systems significant differences are observed between age trend patterns (Badeau 1995, Girardclos 1999). Here, trends observed in even-aged coppice under increasing competition rate are compared with large Eastern France datasets from stands managed as coppice-with-standards and from high forest where oaks selected are mostly regenerated from acorns (Fig. 5). In the case of coppice stand resulting from a clear-cut, shoots from stools analyzed show a growth rate above 3 mm during 3 years and surpassing the one given by other regional silvicultural systems during 5 years. General assumption to explain this fact is that shoot benefit of a fully developed root system. After no more than 10 years, growth rate decrease and can be explained by thinning intensity and competition grade as estimated by tree and stand parameters. But more complicated situations resulting from selective cuts should invite to test the interactions between remaining root system and thinning benefits.

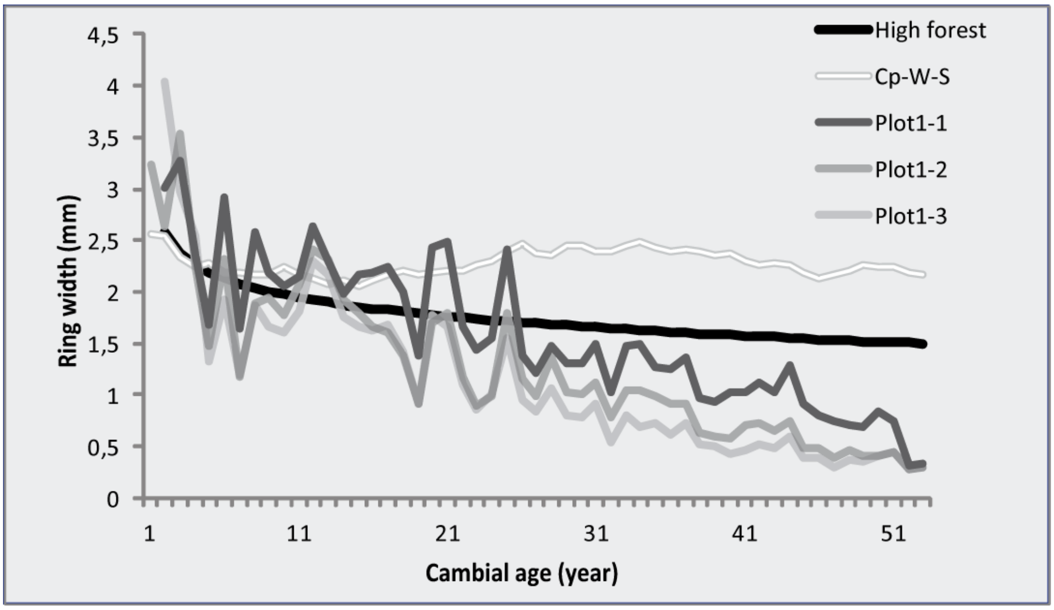

Figure 5: Comparison of cambial age trend computed for shoots of even-aged coppice at plot 1 and regional datasets. Plot1-1 to 3: data ordered in three classes according to the H/D ratio. Cp-W-S: average ring width of 298 trees from forests of French Jura where coppices-with-standards management is well documented (data from Chrono-environnement; Besancon). The curve for high forest is a model adjusted to the data of 505 trees from the forests of Amance and Champenoux (Meurthe et Moselle, France; Becker et al., 1994).

Conclusion

The sampling set allowed outlining some trend differences in ring width series related to coppice management. The first results we present show for the situation sampled (1) that shoots regenerated from stools have a higher growth rate than seed trees in the first 5 years of growth and (2) seed trees studied reach a maximum of productivity after a larger delay of time. However, before to use these observations as references for the past, it is important to raise the structure diversity of stands studied. Investigations of uneven-aged coppices suggest that competition “stories” can be variable even in the very first years of shoot regeneration. Along with the enlargment of this first data set, further work should be directed to the investigations of new plots submitted to other conditions of coppice management and rotations. The question of stand density and wood production will be also matter of study. However, the observations made here are in the spirit of dendrotypology. Conclusions on rate of initial growth, age trend and sapwood proportions are valuable for dendroarchaeological applications, dealing with the reconstruction of past silvicultural practices.

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